



# ***U.S. Army's Ground Vehicle Energy Storage R&D Programs & Goals***



**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**

**James Mainero**

**Energy Storage Team, US Army TARDEC**

**[James.m.mainero.civ@mail.mil](mailto:James.m.mainero.civ@mail.mil) 586-282-9513**

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- **Energy Storage Goals & Mission**
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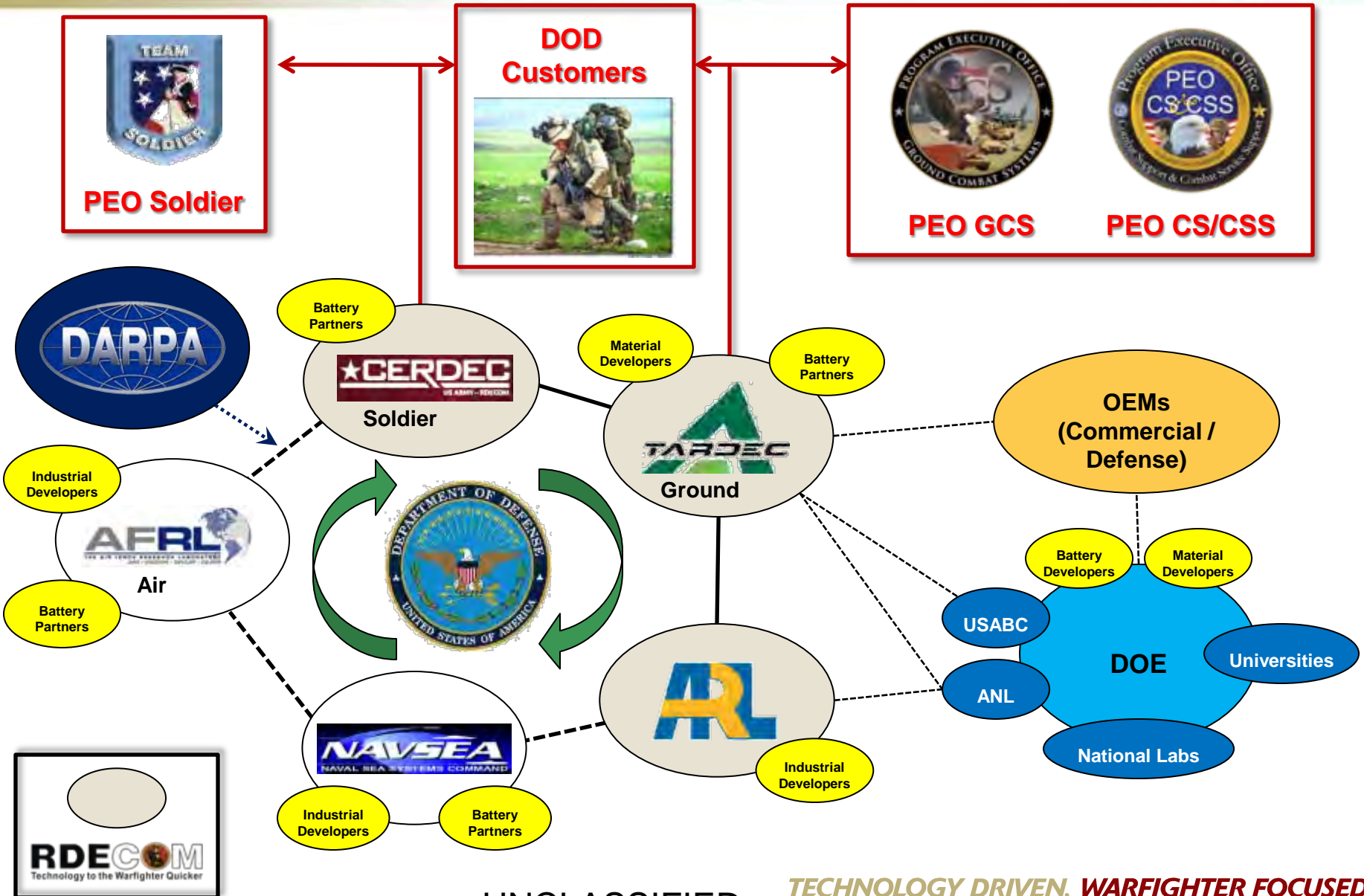
## Energy Storage Goals

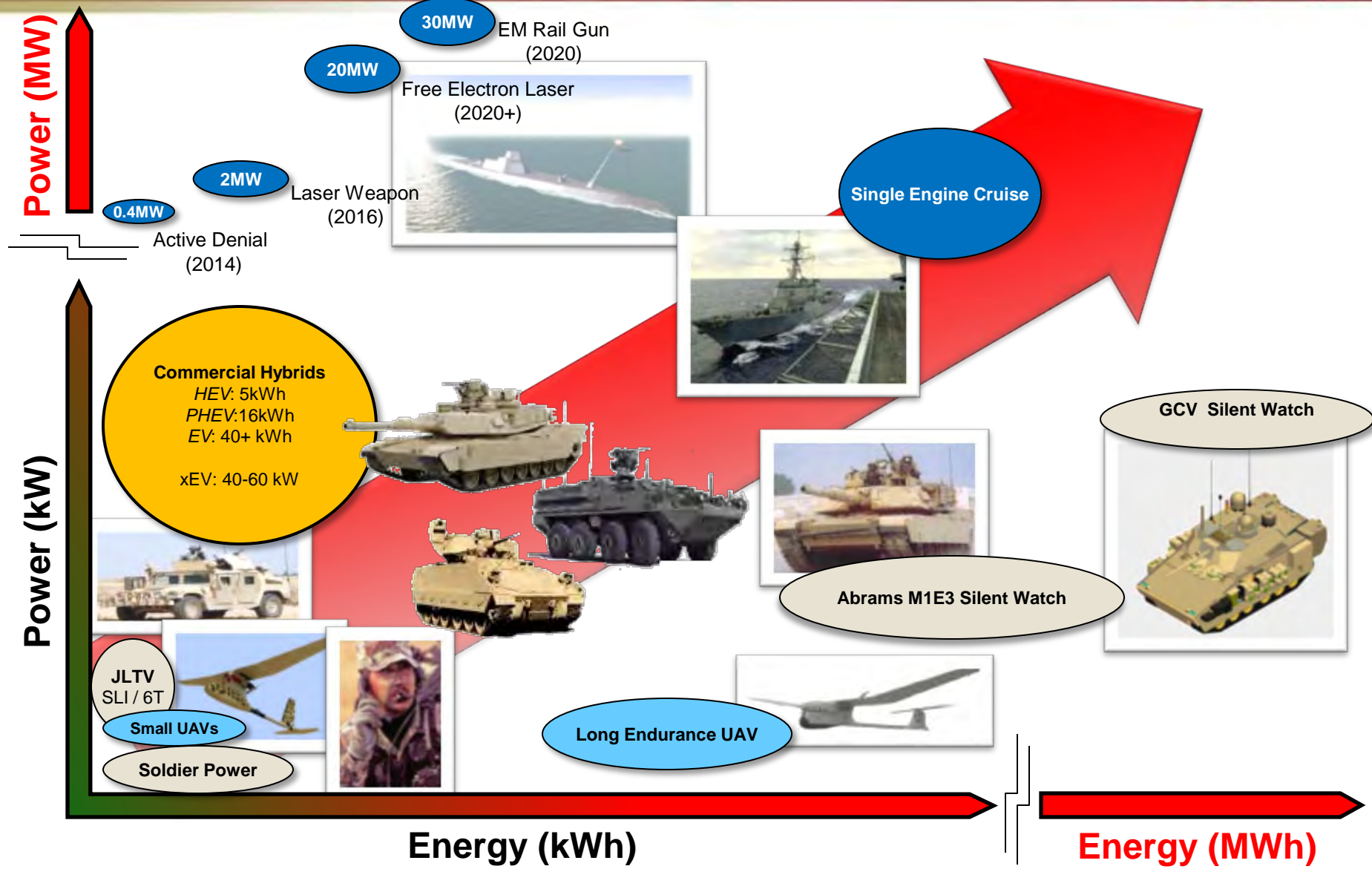
- Develop **safe, reliable and cost** effective energy storage systems
- Reduce **battery weight & volume burden** (Increase Energy & Power Density)
- Reduce logistics and fuel burdens
- Extend **calendar and cycle life**

## Energy Storage Mission

- **Develop** and **mature** advanced ES technologies for transfer to vehicle platforms
- Test & evaluate ES technologies for prequalification and to **assess TRL (Technology Readiness Level)**.
- Identify **technology barriers** and develop technical solutions
- Be recognized as the team of experts in ES components and systems
- Provide technical support to customers, other teams and government agencies for all ES requirements
- Provide **cradle-to-grave** support for all Army ES systems







## Major Applications

- Robotics
- Survivability
- Weapons Systems
- Electromagnetic Armor (EM Armor)
- Starting, Lighting and Ignition (SLI)
- Hybrid Vehicle Acceleration and Silent Mobility
- Silent Watch



Targeting Systems



Hit Avoidance



## Challenges we have:

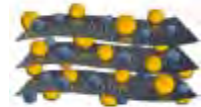
- Delivering reliable battery solutions in standardized military form factors
- Safety – Understanding thermal runaway process and its control, improved BMS and alternative cell technologies.
- Developing energy storage systems with higher energy and higher power densities (focus on designs and chemistries).
- Manufacturing process development, quality and cost control.

## Where we need your help:

- Identify materials/designs/technologies to significantly improve safety
- Develop technologies to improve both energy and power density as well as life (calendar and cycle).
- Develop energy storage systems that focus on standardized form factors (6T, 4HN, Group 31 and Group 34).
- Cost reduction technologies



## Energy Storage Functional Breakdown



### Basic Research

- Lithium plating phenomenon in Li-ion batteries
- **Study on the mechanism of thermal runaway in VRLA Batteries and Methods of Suppression**
- Study of electrode/current collector interface & safe separator for Li-ion batteries
- Development of high energy density anode materials for improved Li-ion batteries
- Alternative electrolyte for use in lithium-ion batteries (higher voltage, improved performance)

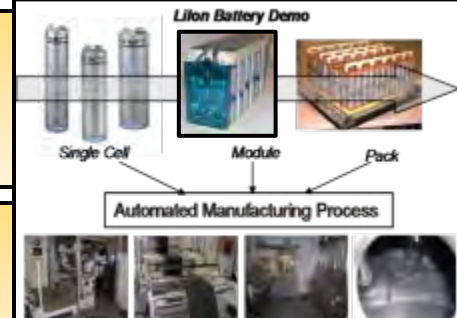
### Applied / Applications Research

- Electromagnetic Armor Power Maturation
- Nickel-Zinc 6T Battery Development
- **Development of 6T battery for SLI and silent watch using Li-ion chemistries**
- Absorbed Glass Matt lead acid battery for 24V military 4HN battery



### Manufacturing

- High Power, High Energy Density Li-Ion Battery Manufacturing Program
- **Lithium-Ion Cell/Battery Pack Manufacturing**
- Advanced battery material scale-up facility



### Battery Management / Safety

- **In-House BMS evaluation for PM HBCT & new laboratory**
- Universal BMS using novel algorithms for battery health
- Ballistic and abuse tolerance studies on cells, module and packs
- Development of advanced diagnostic tools for cycled cells

### Alternative Systems

- Hybrid Power Module
- Lithium-Titanate Hybrid Vehicle Pack Integration
- **Characterization of ultra-capacitors for SLI and high power applications**





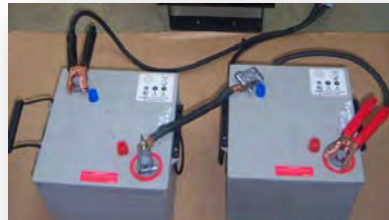
- | 2010   | 2011 | 2012                           | 2013 | 2014   | 2015 | 2016 | 2017 |
|--|------|--------------------------------|------|--|------|------|------|
| High Power, High Energy<br>Li-Ion Battery ATO-M                                  |      | Advanced battery manufacturing |      | Silent Operations Power Source                           |      |      |      |
| Alternative Chemistry 6T<br>Deliverables   |      |                                |      |  |      |      |      |
| Advanced lead Acid Research  |      |                                |      |  |      |      |      |
| PEO GCS Battery Management<br>Specification                                      |      |                                |      |  |      |      |      |
| Battery Management System (BMS)<br>Hardware-in-the-Loop (HIL) – BMS Evaluation   |      |                                |      |  |      |      |      |
| EM Armor Power Brick   |      |                                |      |  |      |      |      |
| Advance Battery Material R&D & Material<br>Scale-up Facility                     |      |                                |      | Silent High Power, High<br>Energy Efficient Power Source |      |      |      |
| Battery Thermal Stability and Electrochemical Properties Testing & Evaluation    |      |                                |      |  |      |      |      |
| Alternative System Evaluation & Development – Safety, Capability,<br>Performance |      |                                |      |  |      |      |      |
- Key:
- |                               |                   |                |
|-------------------------------|-------------------|----------------|
| Alternative Chemistry Battery | Lead Acid Battery | Li-ion Battery |
|-------------------------------|-------------------|----------------|



## Military Lead-Acid 6T Batteries

40Wh/kg  
400W/kg  
~\$350-400/kWh

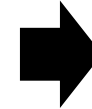
**Baseline**



## Advanced (Ni-Zn or Li-ion) 12V 6T Battery

50-60Wh/kg  
400-450W/kg  
>\$2000/kWhr

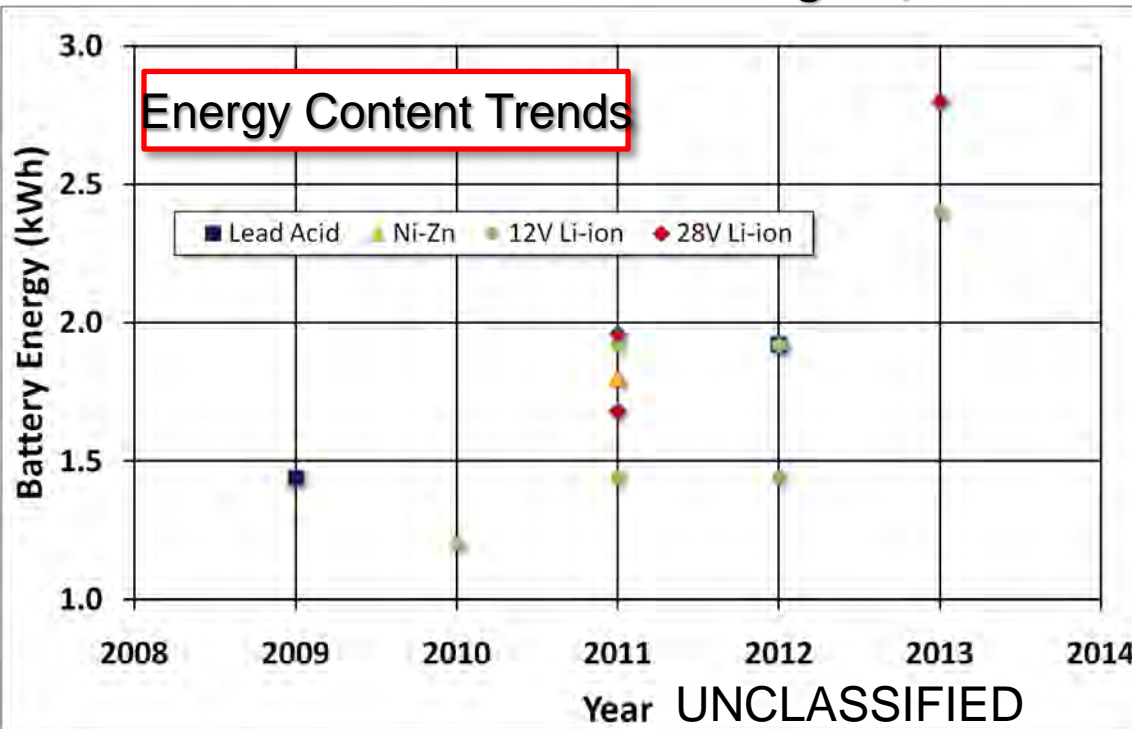
**Lighter, 33% More Energy**



## Li-ion Military Battery Pack Target

>90Wh/kg  
>920W/kg  
<\$800/kWhr

**2-for-1 Drop-in  
Replacement  
½ Volume**



Advanced Battery Technologies Price Targets

Battery Technology	Near-Term	Mid-Term Production	Long-Term High Volume
Lead Acid (12V)	\$400/kWh	\$350/kWh	\$250/kWh
Ni-Zn (12V)	\$500/kWh	\$350/kWh	\$200/kWh
Li-ion (12V or 28V)	\$5,000/kWh	\$1,000/kWh	\$500/kWh

## Current Capability



Battery Testing & Pre-Qualification



Advanced Battery Testing and R&D

- **Lead Acid Battery Laboratory (Bldg 7)** - Supports testing and pre-qualification for military lead acid batteries; 6 water baths, 31 circuits, 1 thermal chamber
- **Electrochemical Research & Analysis Lab (EARL)** - Supports small scale testing for advanced battery chemistries (Li-ion, Ni-Zn) at the cell and module level & battery R&D projects; Walk-in fume hood for safety, 2 explosion resistant thermal chambers, 15 circuits.

## GSPEL

Ground Systems Power  
and Energy Laboratories

## Battery Technology Roadmap

## Future Capability



Battery Pack Storage  
& Shelf Life Testing



Battery Management  
Electronics Laboratory



GSPEL  
Battery  
Test  
Chambers

- **GSPEL Battery Chambers** – 3 Interior & 3 Exterior for safe testing from battery cell to pack level.
- **Battery Management Electronics Lab** – TRL BMS evaluation, Hardware-in-Loop simulation.
- **Battery Storage & Shelf Life Testing** – storage capacity for 26 battery packs or 600 6T batteries



**Federal Business Opportunity Website:**  
**[www.fbo.gov](http://www.fbo.gov)**

- **Broad Agency Announcement**
- **CRADA (Cooperative R&D Agreement)**
- **Education Partnership Agreement**
- **Ground Vehicle Gateway**
- **National Automotive Center**
- **Patent License Agreement**
- **SBIR Program**
- **Test Services Agreement**

**Thank you – This concludes my presentation**



[groundvehiclegateway@conus.army.mil](mailto:groundvehiclegateway@conus.army.mil)

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